PB-241 086

INTERFACING A 24-POINT ANALOG RECORDER TO A COMPUTER CONTROLLED TELEMETRY LINE

John M. Teuschler

National Environmental Research Center
Cincinnati, Ohio

February 1975

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1. REPORT NO.	2.	3. PB 241 086
EPA-670/4-75-002		

4. TITLE AND SUBTITLE
INTERFACING A 24-POINT ANALOG RECORDER TO A COMPUTER CONTROLLED TELEMETRY LINE

5. REPORT DATE
February 1975; Issuing Date

6. PERFORMING ORGANIZATION CODE

7. AUTHOR(S)
John M. Teuschler

8. PERFORMING ORGANIZATION REPORT NO.

9. PERFORMING ORGANIZATION NAME AND ADDRESS
National Environmental Research Center
Office of Research and Development
U.S. Environmental Protection Agency
Cincinnati, Ohio 45268

10. PROGRAM ELEMENT NO.
1HA327; ROAP 01AAD; TASK 10

11. CONTRACT/GRANT NO.

12. SPONSORING AGENCY NAME AND ADDRESS
Same as above

13. TYPE OF REPORT AND PERIOD COVERED

14. SPONSORING AGENCY CODE

15. SUPPLEMENTARY NOTES

16. ABSTRACT
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17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Logic design Logic circuits Control circuits Timing circuits	Controllers Data processing equipment Telemetering data	13B

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18. DISTRIBUTION STATEMENT	19. SECURITY CLASS *(This Report)*	21. NO. OF PAGES
Release to public	Unclassified	33
	20. SECURITY CLASS *(This page)* Unclassified	22. PRICE $3.75

☆ U.S. GOVERNMENT PRINTING OFFICE: 1975-657-591/5341 Region No. 5-11

EPA-670/4-75-002
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INTERFACING A 24-POINT ANALOG RECORDER TO A COMPUTER CONTROLLED TELEMETRY LINE

By

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Methods Development and Quality Assurance
Research Laboratory

Program Element No. 1HA327

NATIONAL ENVIRONMENTAL RESEARCH CENTER
OFFICE OF RESEARCH AND DEVELOPMENT
U.S. ENVIRONMENTAL PROTECTION AGENCY
CINCINNATI, OHIO 45268

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FOREWORD

Man and his environment must be protected from the adverse effects of pesticides, radiation, noise and other forms of pollution, and the unwise management of solid waste. Efforts to protect the environment require a focus that recognizes the interplay between the components of our physical environment--air, water, and land. The National Environmental Research Centers provide this multidisciplinary focus through programs engaged in

- studies on the effects of environmental contaminants on man and the biosphere, and
- a search for ways to prevent contamination and to recycle valuable resources.

This report is part of a continued effort by the Instrumentation Development Branch, Methods Development and Quality Assurance Research Laboratory, NERC, Cincinnati, to evaluate instruments and provide information to both users and suppliers. It is also intended that instrumentation be upgraded and that a choice of the most suitable instrument can be made for a particular application.

A. W. Breidenbach, Ph.D.
Director
National Environmental
Research Center, Cincinnati

ABSTRACT

Interface circuitry was designed so that telemetered data originating from various remote stations could be recorded by both a digital computer and an analog recorder. The entire interface circuitry is mounted on a 3-1/2 x 2-1/2 inch printed circuit card and installed in the receiver. Data from the two methods of collection can, therefore, be collected and a comparison can be made. A switching network also permits computer control with computer and recorder logging; or computer logging only; or recorder logging only.

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SECTION I

SUMMARY

An ASR-33 teletype printer and an analog strip chart recorder can be used simultaneously to collect water quality data. The interface circuitry has been functioning properly ever since the Sprague capacitors and G.E. thyristor were substituted for the previous types.

The only function which could be added to increase the effectiveness of the interface would be a logic circuit used to decide if the print wheel is in the correct position for that particular station. This logic circuit could easily be added if the need would ever arise.

SECTION II

INTRODUCTION

Before the installation of the interface circuitry, water quality data were collected by either the digital computer or the receiver/recorder. Figure 1 shows the results of data collected with both systems in operation and no interface circuitry present. The main obstruction that prevented the simultaneous collection of data was the difference in time base between the two systems. The computer operates on a 10-minute-per-station time base and the receiver/recorder operates on an 8-minute-per-station time base.

The circuitry was designed to provide the capability of collecting data on both systems in unison. Not only can the data acquired by the two methods be compared, but by applying a switching network, either can be used as a back-up logging device.

The control pulses of the interface circuit are limited to an initiating pulse and a finalizing pulse. The initiating pulse could have been derived from either the direct current loop of the network or from the computer. Employing the direct current loop requires a buffer stage to modify the pulse to a transistor switching level. The computer, however, provides a clean "on/off" 5-volt pulse. The design required that the finalizing pulse be taken from the recorder.

To minimize overall wiring and signal sources, the control pulses were derived from the receiver/recorder circuitry. The computer, however, actuates the initiating pulse which is transformed by the receiver into a 110-volt alternating current (AC) signal. This 110-volt signal is used to pulse the interface circuitry.

SECTION III

DESIGN OBJECTIVES

The main functions to be accomplished were to:

1. Start the recorder print wheel within a sufficient time after a station call is initiated by the computer.
2. Stop the recorder print wheel after the eighth point is plotted on the strip chart recorder.
3. Provide the capability of starting the print wheel at the initiation of another station call. (A reset function.)

SECTION IV

INTERFACE THEORY

Figure 2 is a block diagram of a method to accomplish the main objectives. Figure 3 displays the circuitry necessary to perform the functions described in the blocks.

To turn the print wheel motor on at the specified time, blocks #1 through #6 are used. These six blocks accomplish the first main objective which is to turn the recorder print wheel on when a station call is initiated.

Block #2 (isolation and buffer) isolates the 110-volt signal and also steps the voltage down to 6.3 volts and rectifies the alternating current into direct current. Block #3 (station call locator) is a resistor-capacitor (RC) time constant introduced in the circuit to locate the station calls. Since data are transmitted over the line at a much higher frequency than is a station call, a long RC time constant will separate data from a station call. The RC circuit in block #3 will discharge only after a 4-second interval. Because all of the station calls are longer than 4 seconds, each time a station call is made, the "station call locator" will pass a zero pulse to the "interface initiator" (block #4). The interface initiator is a transistor that "turns off" when a zero pulse is applied to the base, thereby turning off relay RY_1 and applying a positive pulse to block #5 (master control). Block #5's transistor is "turned on" by the positive pulse, and relay RY_2 is activated. RY_2 performs three functions when it is activated:

1. The input (A) to the station call locator is removed, thereby allowing the master control to remain in control.

2. Power is applied to the recorder print wheel motor (block #6) that plots the data.
3. The gate circuit to the silicon controlled rectifier (SCR) (block #9) is opened, which allows the silicon controlled rectifier to "turn off" when the positive voltage is removed from its anode.

The second main objective, which is to stop the recorder print wheel after the eighth point is plotted, is accomplished by blocks #7 through #11. The functions of these blocks are described in the following paragraphs.

The master control allows the print wheel (by means of a synchronous motor) to rotate through eight points. On the second point, voltage is removed from block #7 (recorder voltage), thereby "turning off" the SCR in block #9 (reset). The recorder will then rotate through the points in sequence until it gets to the ninth point, which applies a positive 6-volt pulse (indicated by block #7). This pulse passes through the isolation diode (block #8) that keeps any positive pulse from going back into the recorder from the interface, thereby protecting the recorder from an interference by the interface.

The positive pulse also passes through block #9, which is the SCR in the "off state." The pulse then charges the time delay circuit in block #10. This charged timing circuit saturates the transistor in block #11, thereby shorting the base of transistor T_3 to ground. This action "turns off" relay RY_2 which then performs the following functions:

1. The voltage is again applied to the station call locator that removes the positive pulse from the base of transistor

T_3, thereby keeping the master control in the "off state." This action is ensured by the timing circuit in block #10, which keeps transistor T_3 "turned off" for at least 68 milliseconds.

2. The power is removed from the print wheel motor (block #6) after the eighth point is plotted. Therefore, the second main interface function is accomplished.
3. A gate pulse is applied to the SCR in block #9 (reset), which activates the SCR, dropping most of the 6-volt input pulse across resistor R_2. This action allows transistor T_3 to again be turned on when the station locator (block #3) is activated. Therefore, the third main interface function is accomplished by allowing the entire system to reset itself so it can be activated by another station call.

These functions are shown in the synchrogram in Figure 4. In Figure 5 is the final output on the strip chart recorder with the interface circuitry incorporated.

SECTION V

MATHEMATICAL ANALYSIS

The following mathematical analysis refers to the blocks in the schematic and block diagram, Figures 2 and 3.

Block #2 (Isolation and Buffer)

Output voltage of full wave rectifier D_1

$$V_{out} = V_{ac}\sqrt{2} - V_d$$

V_{ac} = 6.3 volts Root Mean Squared (RMS)

V_d = 0.7 volts (diode drop)

$$V_{out} = 6.3\sqrt{2} - 0.7$$

$$V_{out} = 8.2 \text{ volts}$$

Block #3 (Station Call Locator)

This is the 4 second delay designed into the circuit to determine station calls from data transmission.

$$-t_d = RC \ln \frac{V_{csus}}{\quad}\ *$$

RC = (capacitor leakage) = $R_1 + h_{ie,t1}\ C_1$

$RC^{\dagger}$ = (6800 Ω)(250 μf) = 1.7 seconds

$h_{ie,t1}$ = Short circuit input impedance

V_{out} = Voltage of capacitor necessary to sustain relay RY_1 in operation = $(I_{bsus})(R_1) + V_d$

I_{bsus} = Sustaining base current of T_1 = $I_{csus}/h_{fe,ti}$

I_{csus} = Sustaining collector current T_1

$$I_{csus} = \frac{\text{Relay drop voltage}}{\text{Relay resistance}} = \frac{8.1 \text{ volts}}{180\ \Omega}$$

$h_{fe,t1}$ = Short circuit forward current gain

$I_{bsus} = I_{csus}/h_{fe,t1}$ (of T_1) = 45 ma/100 = 450 μa

$V_{csus} = (I_{bsus})(R_1) + V_d$ = (450 μa)(1000 Ω) + 0.7 volts

$$-t_d = RC \ln \frac{V_{csus}}{V_{out}} = 1.7 \text{ seconds } (-2.39)$$

$+t_d$ = 4.06 seconds

*This formula is derived from the capacitor discharge formula:

$V_{csus} = V_{out}\ (e^{-t/RC})$.

†This value for R is an average of the dynamic characteristics.

Block #5 (Master Control)

Triggering of master control relay RY_2

I_{RY_2} = Current necessary to turn relay on

I_{RY_2} = 45 ma (from specifications)

$$I_{c,t3} = (h_{fe,t3})(I_{b,t3})$$

$I_{c,t3}$ = Collector current of transistor T_3

$I_{b,t3}$ = Base current of transistor T_3

$$I_{b,t3} = \frac{V_{cc} - V_d}{R_4}$$

V_{cc} = Power supply voltage

$$I_{b,t3} = \frac{12.0 \text{ v.} - 0.7 \text{ v.}}{1000\ \Omega}$$

$$= 11.3 \text{ ma}$$

Therefore,

$$I_{c,t3} = (100)\ 11.3 \text{ ma}$$

$$I_{c,t3}^{*} = 1.13 \text{ AMPS}$$

*The collector current is therefore more than enough to turn on relay RY_2. Because of the 180 Ω resistance of relay RY_2, the collector current is limited to a 65.5 ma value.

Block #9 (Reset)

Triggering and resetting of SCR

I_{GATE} = 200 μa (maximum from specifications for SCR)

$$I_{R5} = \frac{V_{cc} - V_d}{R5}$$

V_{cc} = Power supply voltage

I_{R5} = Current through R_5

$$I_{R5} = \frac{12.0 \text{ v.} - 0.7 \text{ v.}}{100\text{K } \Omega}$$

$$I_{R5} = 113 \text{ μa}$$

The current I_{R5} is of a sufficient magnitude to gate the SCR into conduction. The saturation voltage (V_{sscr}) of the SCR is 0.7 volts. This is not even enough voltage to overcome the two diode voltages that are in series with transistor T_2. This is shown by the following equation.

$$V_{trig} = I_{b,t2}(R_3) + V_{d4} + V_{d,t2}$$

$I_{b,t2}$ = base current of transistor T_2

$$V_{trig} = I_{b,t2}(R_3) + 0.7 \text{ volts} + 0.7 \text{ volts}$$

V_{trig} has to be at least greater than 1.4 volts in order to activate transistor T_2. Since V_{sscr} = 0.7 v., transistor T_2 is not triggered.

$$V_{trig} = V_{sscr} - (I_{b,t2})(R_3) - V_{d4} - V_{d,t2}$$

Block #10 (Time Delay)

Delay of one RC Time Constant

D_4 - Charges C_2 and then prevents the capacitor from discharging when the SCR is fired.

RC time delay $= (R_3 + h_{ie,t2})\, C_2$

$$h_{ie,t2} = (m)(h_{fe,t2})\ \frac{V_t}{I_{eq}}$$

$m = 1.4$ for Si transistors

$V_t = 25$ mv. @ 72°F

$$I_{eq} = \frac{V_{cc} - V_{sat,t2}}{R4}$$

$V_{sat,t2} = 0.2$ volt

$I_{eq} = 1.8$ ma

$$h_{ie,t2} = \frac{(1.4)(100)(.025)}{(.0118)}$$

$h_{ie,t2} = 296\ \Omega$

RC time delay* $= (R_3 + h_{ie,t2})\, C_2$

RC time delay $= (1k\ \Omega + 296\ \Omega)\ 68\ \mu f$

RC time delay $= 88$ msec (for one time constant @ $1_{eq} = 11.8$ ma)

*This delay allows the contacts to block "A" to give a strong voltage pulse to Block #3 (station call locator in Figure 3).

Block #11 (Master Stop)

Saturation of Transistor T_2

$I_{c,t2} = (h_{fe,t2})(I_{b,t2})$

$I_{c,t2}$ = Collector current of transistor T_2

$h_{fe,t2}$ = Short circuit forward current gain of T_2

$I_{b,t2}$ = Base current of transistor T_2

$$I_{b,t2} = \frac{\text{Rcdr.}^{*}\ \text{Volt.} - V_{d2} - V_{d4} - V_{d,t2}}{R_2 - R_3}$$

$$I_{b,t2} = \frac{6 - 0.7 - 0.7 - 0.7}{1K + 1K}$$

$I_{b,t2} = 1.95$ ma

$I_{c,t2} = (100)(1.95\ \text{ma})$

$I_{c,t2} = 195$ ma

$I_{c,t2}$ = Sufficient current to saturate transistor T_2

$V_{CE\ SAT}^{+}$ = 0.2 v with R_4 connected in series with the collector-emitter terminals

---

* Rcdr. = Recorder

+ Since transistor T_3 needs 0.745 volt to operate relay RY_2, the saturation of transistor T_2 drops this voltage to 0.2 volt, thereby turning off transistor T_3 and deactivating relay RY_2.

SCR in conducting state

$$I_{scr} = \frac{V_{cc} - V_{d2} - V_{dscr}}{R_2}$$

$$I_{scr} = \frac{12 - 0.7 - 0.7}{1K}$$

I_{scr} = 10.6 ma (well within limiting characteristics of 4 amperes)

SCR in nonconducting state

SCR acts as an open circuit

I_{scr} = 0.0

SECTION VI

FABRICATION AND INSTALLATION

A prototype engineering model was assembled on a 3-1/2 x 2-1/2 inch printed card. Etching techniques were used to make connections among the components. All components are shown in their respective positions on the printed circuit card layout (Figure 6).

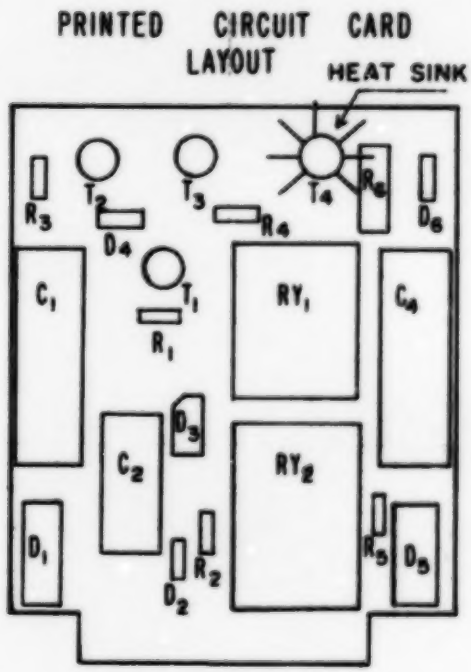


Figure 6. Top view showing component locations

The reason for keeping the interface compact can be seen from the lack of space in the receiver (Figure 7).

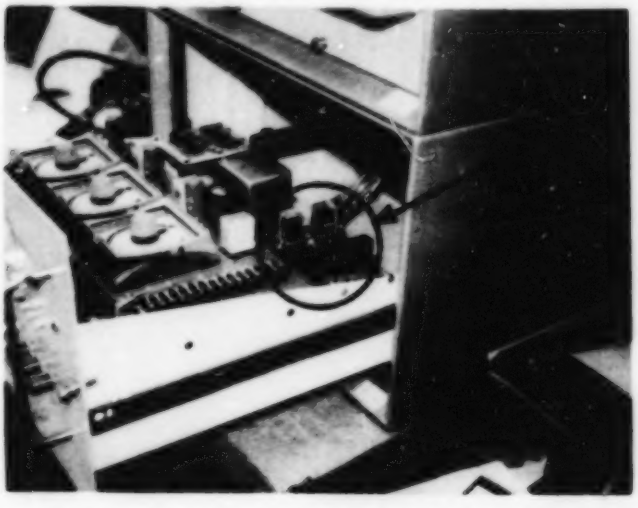
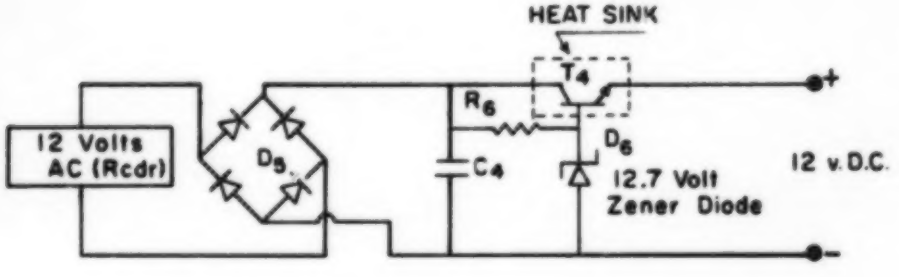


Figure 7. Interface shown installed in receiver/recorder

The interface's total support comes from a 10-pin cinch connector mounted in the side of the receiver; therefore, space and weight had to be kept to a minimum. This was accomplished easily using the printed circuit card techniques mentioned above.

Power for the printed circuit card comes in the form of a 12-volt regulated power supply (Figure 8).



This power supply is mounted in the printed circuit card with the other components.

Total cost of the entire interface less labor was approximately $18. This includes connector, printed circuit board, relays, and all other electronic components.

SECTION VII

TESTING

The interface circuit was operated for 6 months in the receiver before a final design was fabricated. The failures that occurred resulted from the electronic components, which were used within their specifications.

Most failures resulted from the Centralab capacitors, C_1 and C_4 (Figure 3) rated at 15 volts for 250 μf, opening their circuit after a few months of operation. The problem was corrected by using Sprague capacitors rated at 25 volts for 250 μf.

Another failure was caused by a Motorola thyristor (HEP 320) short-circuiting after a few months of operation; the device was rated at 800 ma. This problem was corrected by using a GE thyristor (C106B2) rated at 4000 ma.

The final design was fabricated after the testing (Figure 9). The final design incorporated the described changes, i.e., Sprague capacitors and a G.E. thyristor.

SECTION VIII

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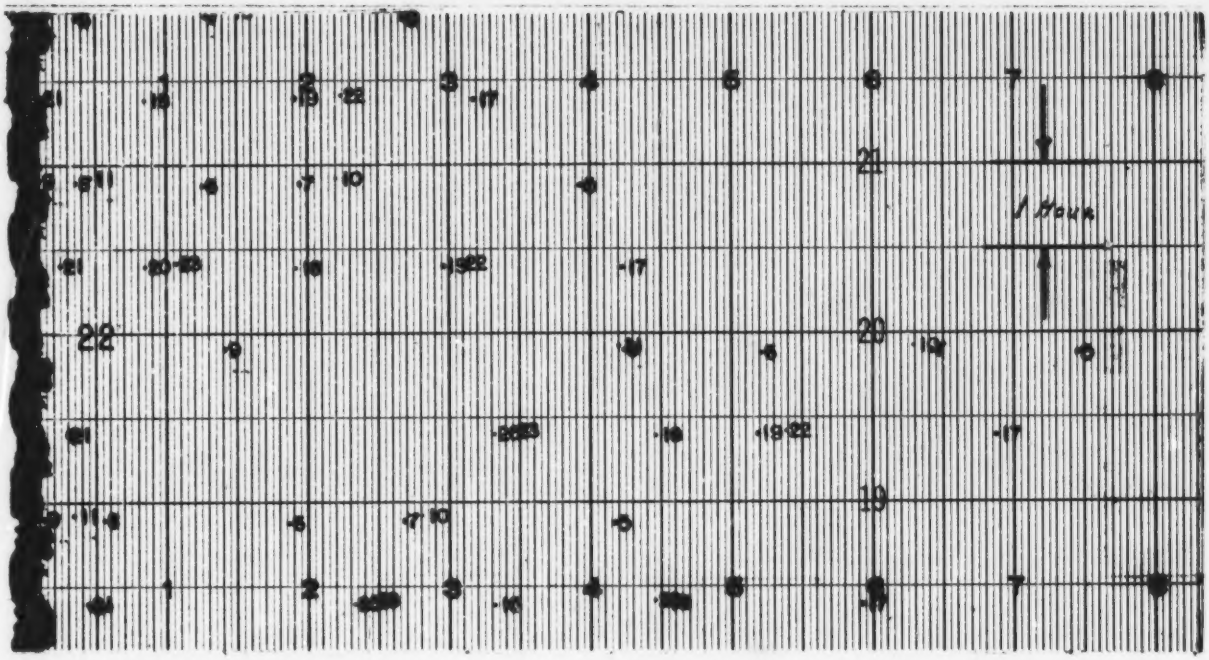
APPENDIX A



LEGEND

STATION LOCATION PARAMETER	1 LMR NUMERICAL	2 LAB IDENTIFICATION	3 GMR
Test	1	9	17
pH	2	10	18
Cond.	3	11	19
Blank	4	12	20
D.O.	5	13	21
Temp.	6	14	22
SRI	7	15	23
Blank	8	16	24

Figure 1. Data collected on analog strip chart recorder with computer employed in network and no interface between computer and recorder. Note that a data word is logged with varying numerical identification.

APPENDIX B

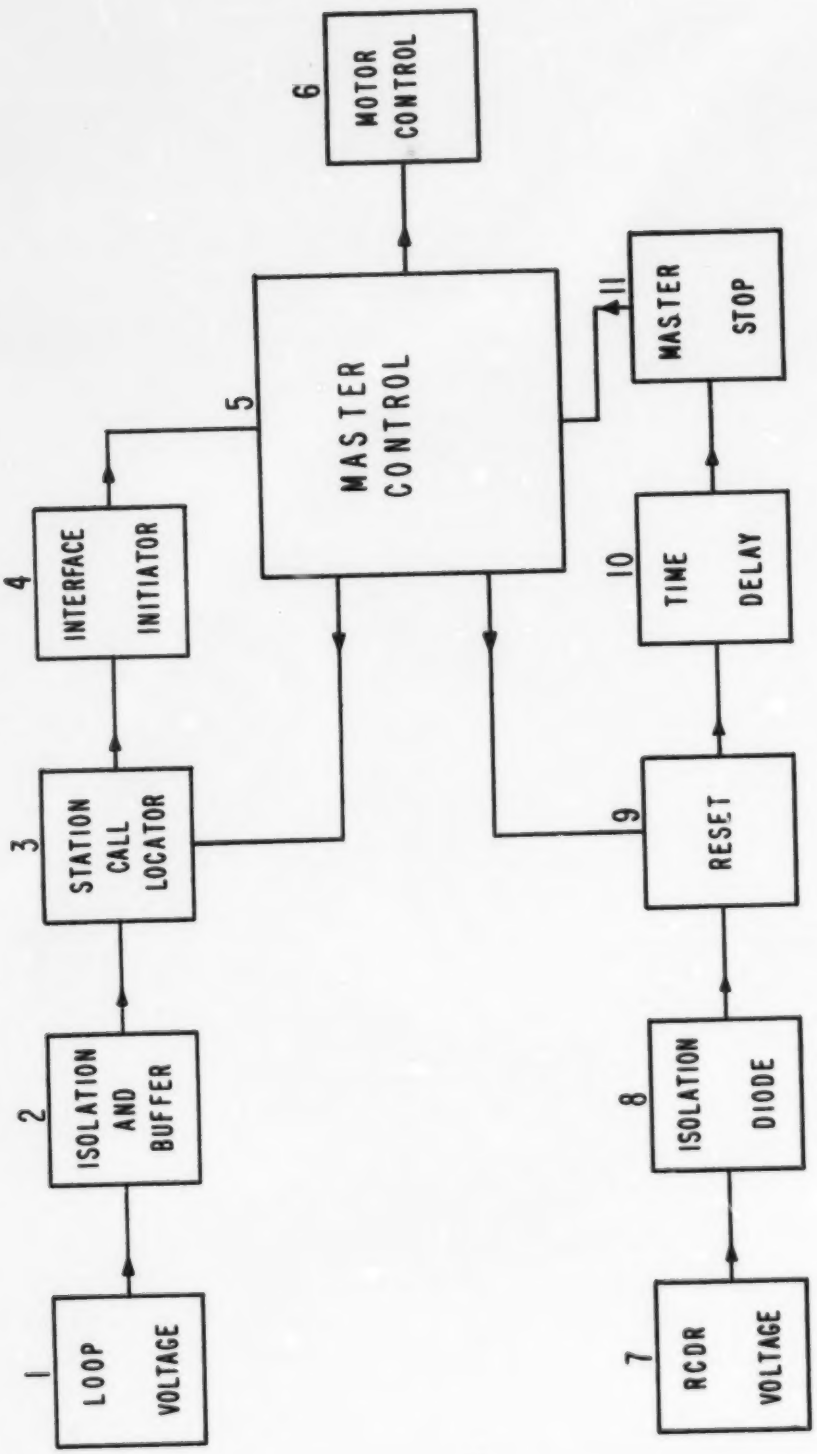


Figure 2. The interface block diagram showing the directional control between the blocks.

APPENDIX C

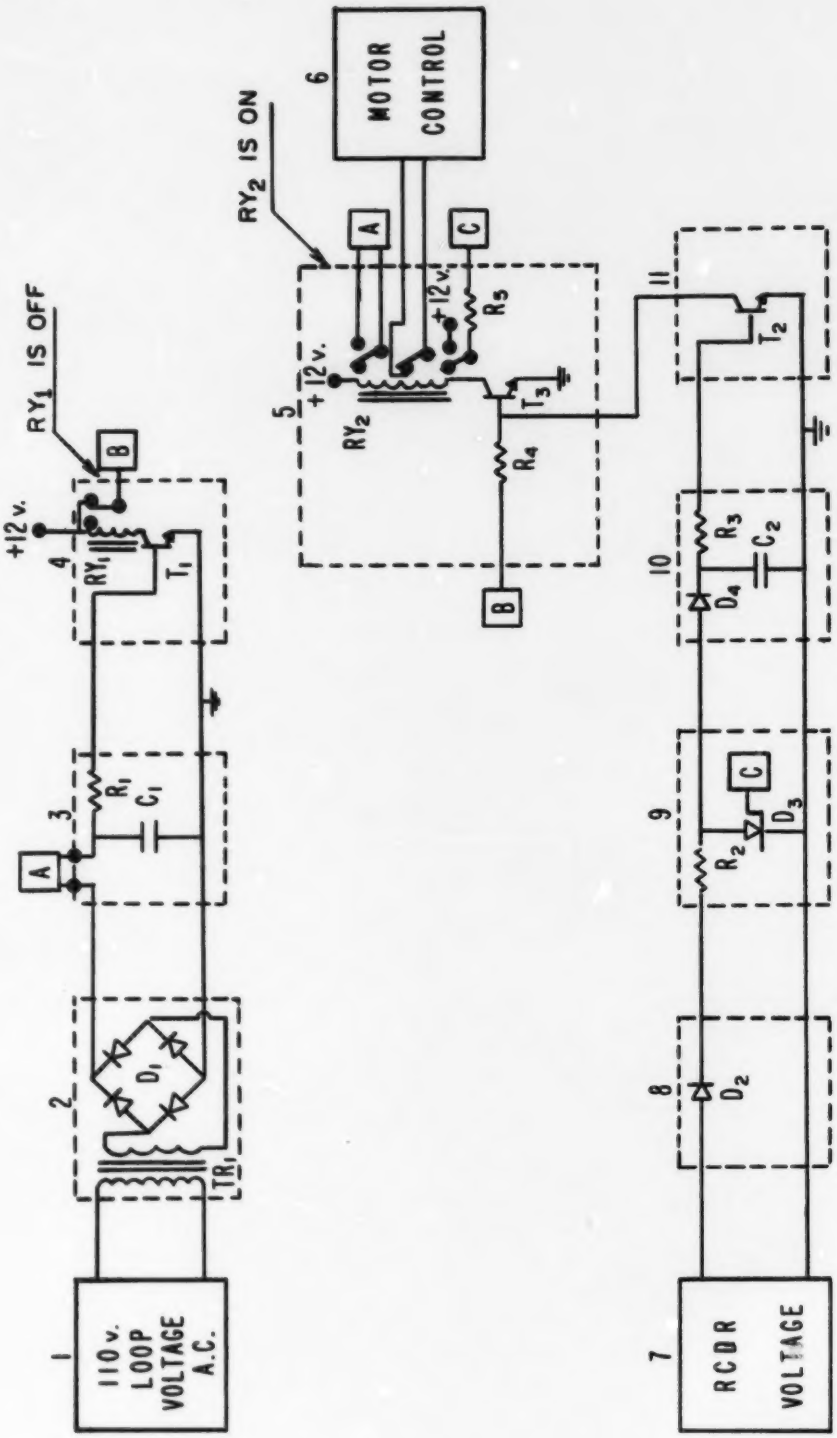


Figure 3. Interface circuit schematic.

APPENDIX D

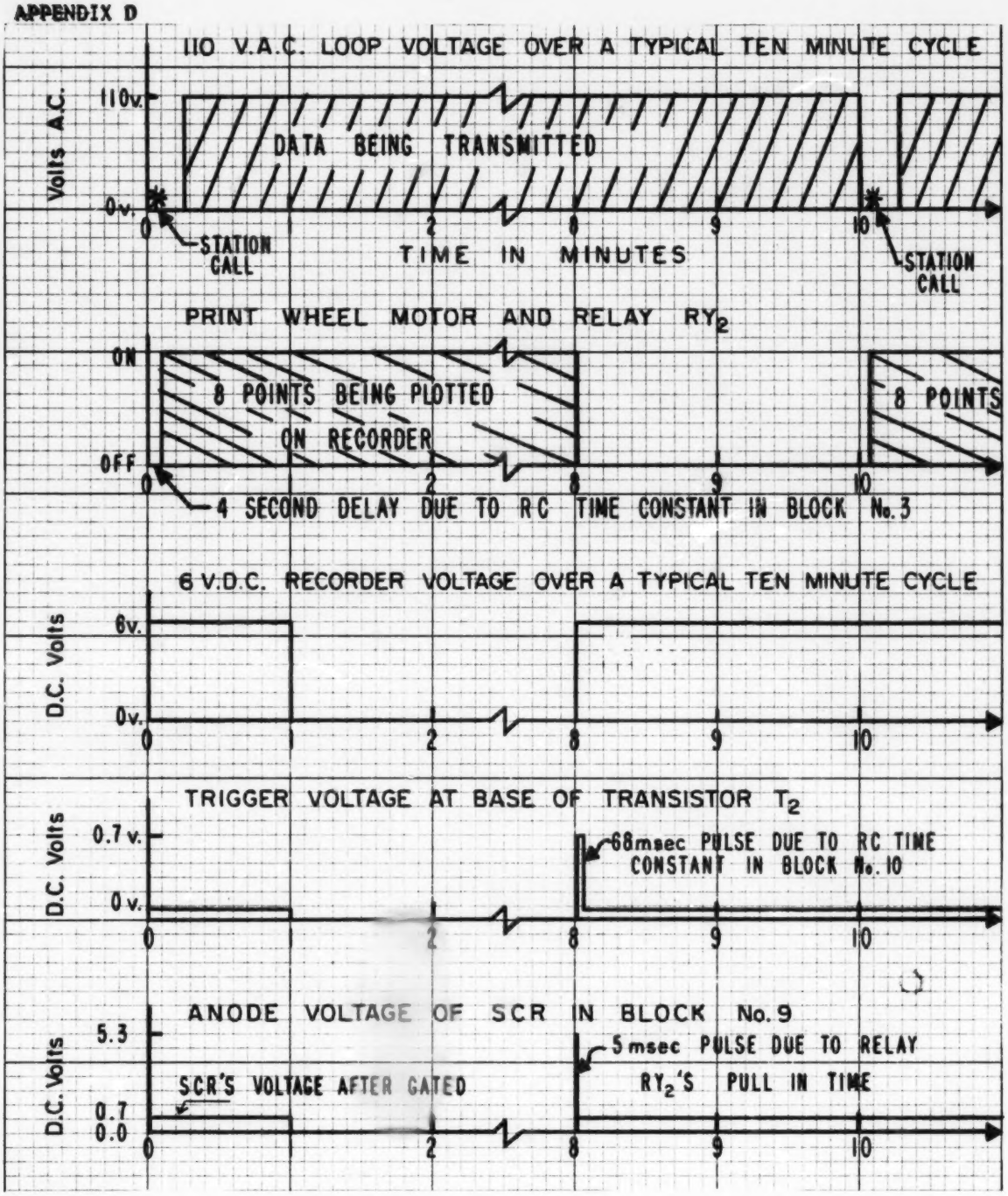
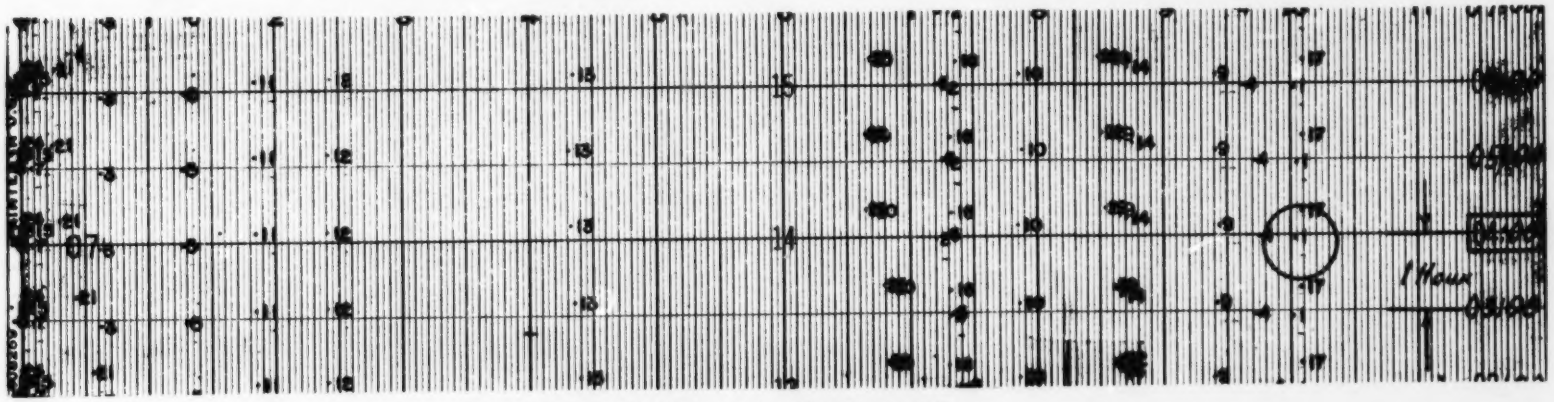


Figure 4. Interface synchrogram.



Data collected from strip chart recorder.
(Note comparative data in Figure 1) Legend (see Figure 1)

DAY	TIME	S	TEST	PH	CONH	DCL	DO	TEMP	TURB	SRI	ST	FLOW
172	03:00	1	1012	07.32	0240	142	02.56	072.8	0000	0.00	0	0000
172	03:10	2	0948	07.84	0752	048	08.64	087.6	0008	0.00	0	0000
172	03:20	3	1024	07.28	3472	136	00.48	086.0	1352	0.00	0	0000

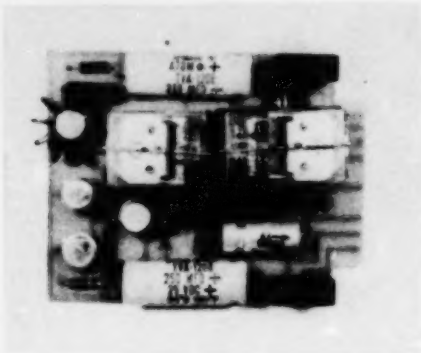
DAY	TIME	S	TEST	PH	CONH	DCL	DO	TEMP	TURB	SRI	ST	FLOW
172	04:00	1	1012	07.32	0256	152	02.56	072.4	0000	0.00	0	0000
172	04:10	2	0948	07.84	0736	048	08.64	088.0	0000	0.00	0	0000
172	04:21	3	1020	07.28	3456	136	00.00	085.2	1360	0.00	0	0000

DAY	TIME	S	TEST	PH	CONH	DCL	DO	TEMP	TURB	SRI	ST	FLOW
172	05:00	1	1012	07.28	0240	152	02.64	072.0	0000	0.00	0	0000
172	05:10	2	0948	07.88	0752	048	08.64	088.0	0000	0.00	0	0000
172	05:21	3	1020	07.32	3456	136	00.40	084.8	1344	0.00	0	0000

Corresponding data collected from digital computer.

Figure 5. Data collected in unison employing the interface circuitry.

APPENDIX F



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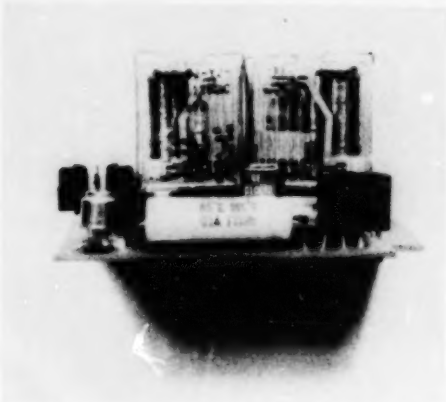
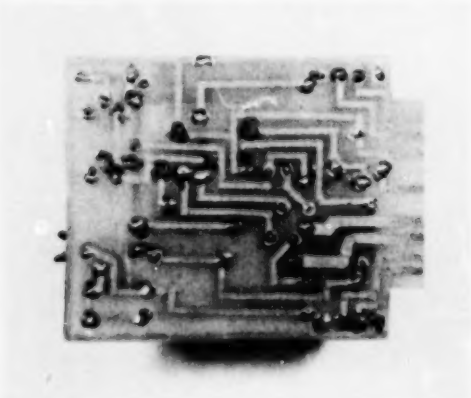
Top view showing physical layout of components



Side view showing relative heights of components



Bottom view showing etching techniques incorporated

Figure 9. Photographs of the interface circuit.

APPENDIX G

PARTS LIST

R_1 - 1K OHMS (part of an RC 4 second delay circuit)
R_2 - 1K OHMS (Current limiter for SCR)
R_3 - 1K OHMS (Bias resistor for T_2)
R_4 - 1K OHMS (Bias resistor for T_3)
R_5 - 100K OHMS (Bias resistor for SCR trigger)
R_6 - 1K OHMS (Bias resistor for T_4)
C_1 - 250 µf (part of an R_1C_2 4 second delay circuit)
C_2 - 68 µf (Delay capacitor)
C_4 - 250 µf (Filter capacitor)
D_1 - 6941 Mallory (Full wave rectifier bridge)
D_2 - (Insolation diode)
D_3 - C106B2 (SCR)
D_4 - 1N1521A (part of R_5C_2 time constant circuit)
D_5 - 6941 Mallory (Full wave rectifier bridge)
D_6 - Motorola (12.7 volt zener diode)
T_1 - 40346 (Relay RY_1 control)
T_2 - 2N697 (Short circuits T_3 to ground)
T_3 - 2N697 (Relay RY_2 control)
T_4 - 2N697 (Voltage regulator)
TR_1 - (110V. to 6.3V. isolation transformer)
RY_1 - 2P2T 12 volt Potter Brumfield relay
RY_2 - 4P4T 12 volt Potter Brumfield relay